Neurology Asia 2023; 28(2) : 297 – 306

Endoscopic third ventriculostomy versus ventriculoperitoneal shunt in pediatric patients with post-infective hydrocephalus: A meta-analysis of randomized controlled trials

Fenjie Lin *MD*, Xun Zhang *MD*, Yinghua Rao *MD*, Shuchang Zheng *MD*, Biyan Liang *MD*, Mingjun Qin *MD PhD*

Department of Neurosurgery, The Affiliated Brain Hospital of Guangzhou Medical University, Guangzhou, China.

Abstract

Background: Although studies on the safety and efficacy of endoscopic third ventriculostomy (ETV) and ventriculoperitoneal shunt (VPS) have been conducted, the safety and efficacy for treating post-infective hydrocephalus (PIH) in pediatric patients have not been investigated using meta-analysis and thus remain controversial. Therefore, we conducted a meta-analysis to assess the safety and efficacy of ETV and VPS for PIH treatment and determine whether ETV is more appropriate than VPS for treating PIH in PP. *Methods:* We searched Pubmed, Embase, Web of Science, and the Cochrane Library databases up to January 2022. The quality of studies was assessed using the Cochrane Collaboration's tool for assessing the risk of bias in randomized trials. A fixed-effect model was used for pooling analysis, and heterogeneity was assessed using I^2. *Results:* Three randomized controlled trials involving 200 patients out of a total 254 identified studies were included. No significant differences were found between ETV and VPS in postoperative success rate (risk ratio RR: 0.89; 95% confidence interval CI: 0.72–1.10; $p = 0.27$), postoperative infection rate (RR: 0.68; 95% CI: 0.21–2.22; $p = 0.52$), postoperative blockage rate (RR: 0.90; 95% CI: 0.40–2.00; $p = 0.80$), complication rates (RR: 1.29; 95% CI: 0.45–3.71; $p = 0.63$), or mortality (RR: 1.31; 95% CI: 0.47–3.65; $p = 0.60$). However, patients who underwent VPS showed lower postoperative cerebrospinal fluid leakage than those who underwent ETV (RR: 9.00; 95% CI: 1.18–68.45; $p = 0.03$).
Conclusions: VPS may be more beneficial for the treatment of PIH in pediatric patients.

Keywords: Endoscopic third ventriculostomy, pediatric, post-infective hydrocephalus, ventriculoperitoneal shunt

INTRODUCTION

Infection, brain tumors, cranioencephalic malformations, and intracranial hemorrhage can cause hydrocephalus.[1,2] Hydrocephalus can lead to increased intracranial pressure, which may lead to headache, vomiting, cranial nerve injury, consciousness disorder, and even death in severe cases, especially in children.[3] Post-infective hydrocephalus (PIH) is the most common form of hydrocephalus worldwide in pediatric patients (PP)[3,4] and is primarily caused by virus, fungi, or bacteria.[5]

Currently, the main treatments for hydrocephalus are surgical interventions, such as ventriculoperitoneal shunt (VPS) and endoscopic third ventriculostomy (ETV) with or without choroid plexus cauterization (ETV-CPC). VPS is considered the standard treatment for hydrocephalus over ETV.[6,7] However, recent studies have shown that ETV has a significantly lower risk of surgery-related complications than VPS[8,9], although Pande *et al*.[10] recommend further research to identify specific patient populations that are better suited for ETV or VPS. There are specific endoscopic challenges that occur as a result of abnormal or indistinct third ventricular

Address correspondence to: Mingjun Qin, M.D., Ph.D., Department of Neurosurgery, The Affiliated Brain Hospital of Guangzhou Medical University, Guangzhou 510370, China. E-mail: gynksjwk@163.com

Date of Submission: 1 December 2022; Date of Acceptance: 12 March 2023

https://doi.org/10.54029/2023dhw

anatomy, such as tuberculous meningitis, and because hydrocephalus presents during the acute phase of the disease, rather than being a post-infectious condition.[11]

ETV has been widely used to treat hydrocephalus, although primarily in adults. Although ETV has shown encouraging results in older children, outcomes are poorer in younger children.[12,13] Moreover, ETV is not recommended in neonates because of technical difficulties and poor absorption capacity.[14] Furthermore, the success rate of ETV for treating PIH is lower than that of VPS.[15,16] Currently, the outcomes following ETV and VPS for the treatment of PIH in pediatric patients remain controversial. Therefore, we conducted a meta-analysis of all RCTs to access the safety and effectiveness of the procedures and determine whether ETV is more appropriate than VPS for treating PIH in PP based on clinical outcomes (postoperative success rate), major complications, and mortality. This meta-analysis will offer guidance for future studies on the treatment of PP with PIH.

METHODS

The methodology of this study followed the Preferred Reporting Items For Systematic reviews and Meta-Analyses guidelines.[17] The protocol was registered on the PROSPERO database (CRD42022311989).

Search strategy and selection criteria

Four electronic databases were used for the literature search, including Pubmed, Embase, Web of Science, and the Cochrane Library, to search for articles from electronic database inception to January 31, 2022. The following keywords were searched: 'hydrocephalus' and 'ventriculostomy'. We also manually searched the references of the included studies to identify further eligible studies. Two investigators extracted and summarized the search results independently. Disagreements were resolved by consensus.

All articles fulfilled the following inclusion criteria: (1) RCTs comparing VPS with ETV (or ETV-CPC), with quantitative data on the clinical outcomes of interest; (2) all included patients were pediatric (aged ≤ 18 years); and (3) all included PP had PIH. Exclusion criteria were as follows: (1) letters, review articles, case reports, or studies in languages other than English; (2) studies that enrolled adults; (3) not an RCT; (4) patients had other types of hydrocephalus; and (5) patients had prior ventriculostomy or shunt surgery. (6) Due to the complex treatment of multiloculated hydrocephalus[18-20], which was different from the ETV and VPS surgical modalities, it was excluded.

Data extraction and outcomes

The data were extracted from the eligible studies by two authors independently. The relevant variables extracted included author, year of publication, surgical methodology, number of patients per group, design of the study, etiology of hydrocephalus, age, sex, follow-up time, number of successful cases, mortality rate, and number of complications (e.g., postoperative cerebrospinal fluid (CSF) leakage, postoperative infection, and postoperative blockage, which is regarded as an inadequate stoma in the ETV group or shunt malfunction in the VPS group post-surgery). Surgical procedure success was defined as patients who showed improvements in clinical and radiological profile or did not require a second operation.

Risk of bias assessment

The quality of the enrolled RCTs was assessed by two authors independently using the Cochrane Collaboration's tool for assessing the risk of bias in randomized trials.[21]

Statistical synthesis and analysis

A dichotomous variable risk ratio (RR) or odds ratio (OR) with a 95% confidence interval (CI) was used to represent the probability of an event occurring. Heterogeneity was assessed using the I^2-test metric. There was no significant heterogeneity when I^2 was less than 50%[22], in which case a fixed-effects model was used. Otherwise, a random-effects model was used.[22] The Rev-Man software (version 5.3) was used for all statistical analyses. Statistical significance was set at $p < 0.05$.

RESULTS

Search results

Our search strategy identified 254 potentially relevant studies. Finally, three RCTs[23-25] were included in the meta-analysis (Figure 1).

Characteristics of the included studies and quality assessment

Table 1 shows the characteristics of the included articles.[23-25] The ETV-CPC surgical method[25]

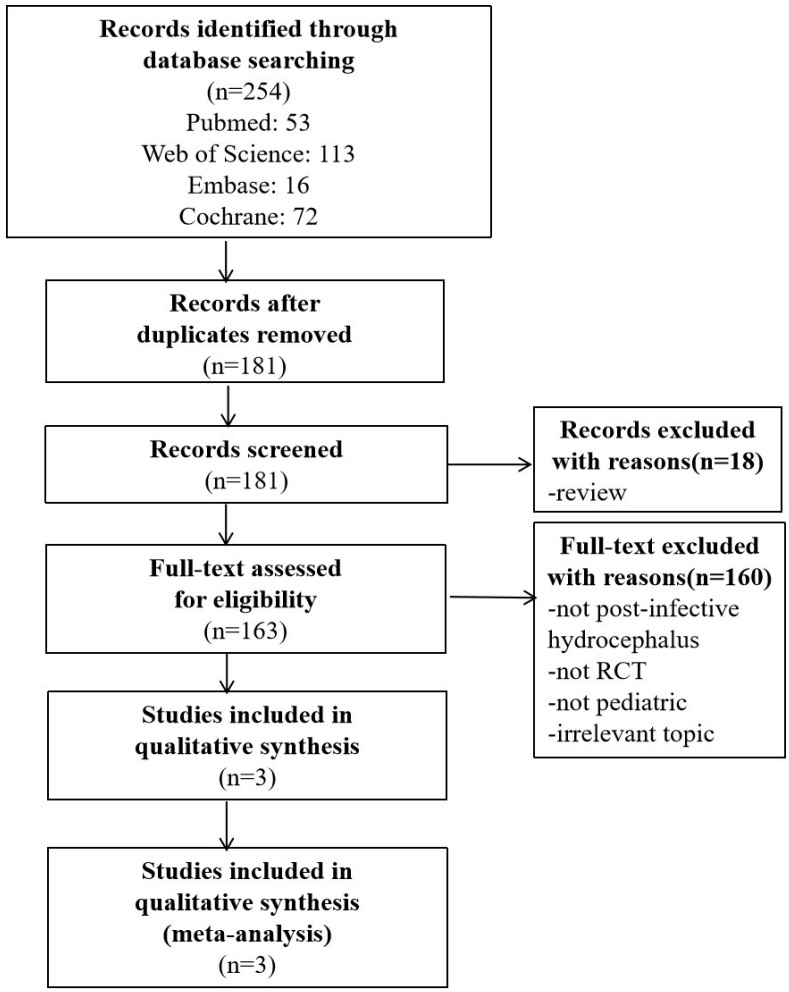

Figure 1. Flow charts for PRISMA search.

was used in one of the articles. This article was included and considered as ETV because the ETV surgical method played a major role in the surgical procedure. A total of 200 patients were enrolled across the three studies, which comprised 101 patients in the ETV group and 99 patients in the VPS group. All studies[23-25] reported the postoperative success cases (ETV group: 60; VPS

Table 1. Characteristics of included studies

Study	Study design	Number of patients ETV/VPS	Etiology of hydro-cephalus	Age ETV/VPS	Follow-up time	Intervantion/ operation	Female ETV/VPS
Aranha *et al*. 2018[20]	RCT	26/26	Tubercular meningitis	NR in the grouping	A minimum of 5 months	ETV/VPS	11/10
Goyal *et al*. 2014[21]	RCT	24/24	Tubercular meningitis	4.4±4.60/ 4.31±3.72 (years)	6 months	ETV/VPS	7/7
Kulkarni *et al*. 2017[22]	RCT	51/49	NR	2.6- 4.1/ 2.7 - 3.9 (month)	12 months	ETV/VPS	21/18

RCT, randomized controlled trial; ETV, endoscopic third ventriculostomy; VPS, ventriculoperitoneal shunt; NR, not reported

group: 66), the postoperative infection cases (ETV group: 4; VPS group: 6), and the mortality cases (ETV group: 8; VPS group: 6). Two articles[23-24] reported the CSF leakage cases (ETV group: 8; VPS group: 0). Postoperative blockage occurred in 19 patients (ETV group: 9; VPS group: 10) across two studies.[23-24]

According to the Cochrane Handbook for Systematic Reviews of Intervention (version 5.0.2), we assessed the risk of bias in the included studies using the criteria of the risk of bias assessment tool. All studies described the method of randomization. Because patients' family members had the right to know about the operation before the surgery, the blinding of patients, family members, and researchers was impossible across all studies. Therefore, the lack of blinding is unlikely to affect the final results. One[25] of the RCTs was of high quality with a low risk of bias in all domains; however, the quality of the remaining two articles was unclea[23-24] because they lacked information on allocation concealment. The risk of attrition bias was high in the study by Goyal *et al*.[24] because of the population loss. Figure 2 shows the quality assessment of the included studies.

Postoperative success

For postoperative success rate, all three studies reported a specific number of successful surgeries (126/200, 63%). The pooled data showed that there was no significant difference in the rate of success between the ETV and VPS groups (RR: 0.89; 95% CI: 0.72–1.10; p = 0.27), and there was no significant heterogeneity (I^2: 0%; p = 0.60; Figure 3).

Postoperative CSF leakage

Two articles reported complications of

Figure 2. Risk of bias summary.

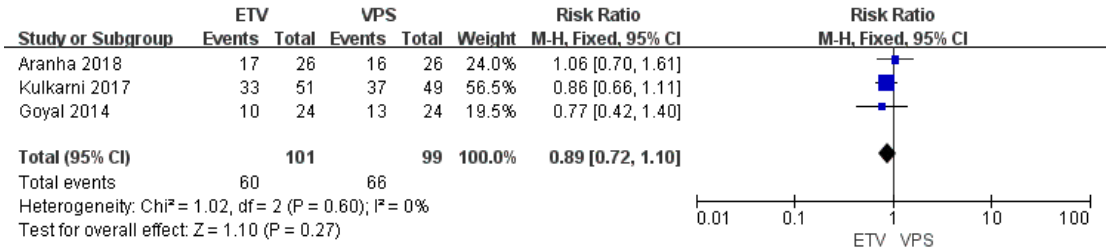

Figure 3. Forest plot for postoperative success rate.

postoperative CSF leakage. In the ETV group, CSF leakage occurred in eight patients, whereas no patients in the VPS group experienced CSF leakage. After pooling the data, we found that the incidence of CSF leakage in the VPS group was significantly lower than that in the ETV group (RR: 9.00; 95% CI: 1.18–68.45; p = 0.03; I^2: 0%; Figure 4).

Postoperative infection

There were four cases of postoperative infection in the ETV group and six cases in the VPS group. There was no significant difference in the incidence of postoperative infection rate between the two groups when data were combined (RR: 0.68; 95% CI: 0.21–2.22; p = 0.52), and there was no significant heterogeneity (I^2: 2%; p = 0.36; Figure 5).

Postoperative blockage

Two of the included RCTs provided data on postoperative blockage. In the ETV group, 18% of patients experienced inadequate stoma or stoma malformation, and 20% of patients in the VPS group experienced shunt malfunction following surgery. The incidence of postoperative blockage was similar across the two groups (RR: 0.90; 95% CI: 0.40–2.00; p = 0.80), and there was no significant heterogeneity (I^2: 0%; p = 0.86; Figure 6).

Complication rates in general

The complication rates in general was similar across the two groups (RR: 1.29; 95% CI: 0.45–3.71; p = 0.63), and there was no significant heterogeneity (I^2: 62%; p = 0.07; Figure 7)

Mortality

In the ETV and VPS groups, the mortality rates were 7.9% and 6.1%, respectively. After pooling the data, there was no significant difference in overall mortality between the two groups in the treatment of PIH in pediatric patients (RR: 1.31; 95% CI: 0.47–3.65; p = 0.60), and there was no significant heterogeneity (I^2: 0%; p = 0.83; Figure 8).

DISCUSSION

A recent meta-analysis revealed a higher incidence of hydrocephalus in the pediatric age group than in adults and older adults.[26] When hydrocephalus is caused by an infective agent, it is defined as PIH and is the most difficult to manage of all the types of hydrocephalus. Both communicating and non-communicating hydrocephalus can be caused by PIH.[16] With recent developments in endoscopy, ETV has a high success rate in the treatment of hydrocephalus.[16,24,27-30] However, Pinto *et al*.[31] reported that VPS is a superior method over ETV because it offers better functional neurological

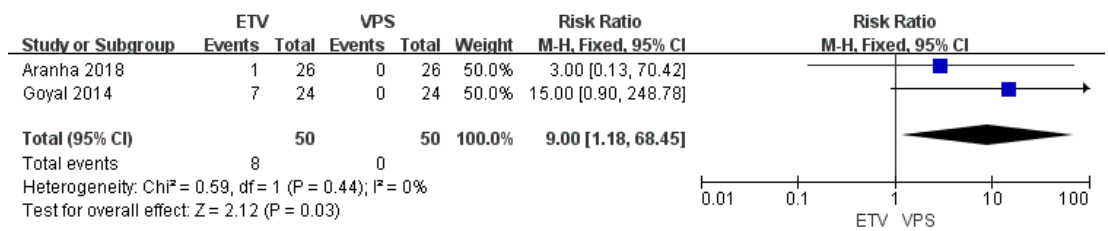

Figure 4. Forest plot for postoperative CSF leakage rate.

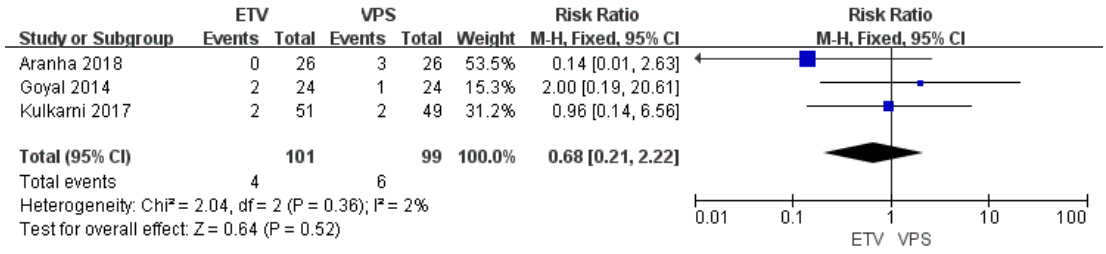

Figure 5. Forest plot for postoperative infection rate.

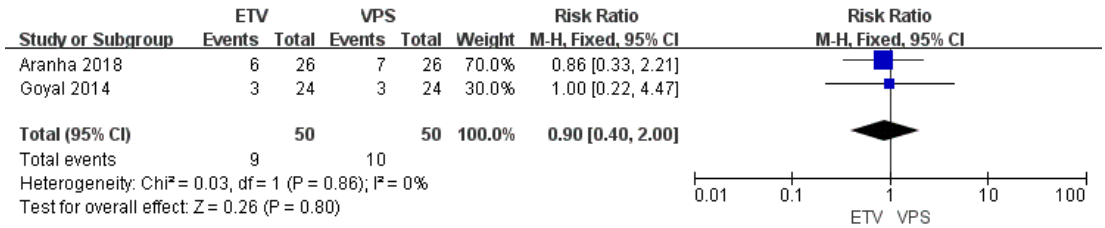

Figure 6. Forest plot for postoperative blockage rate.

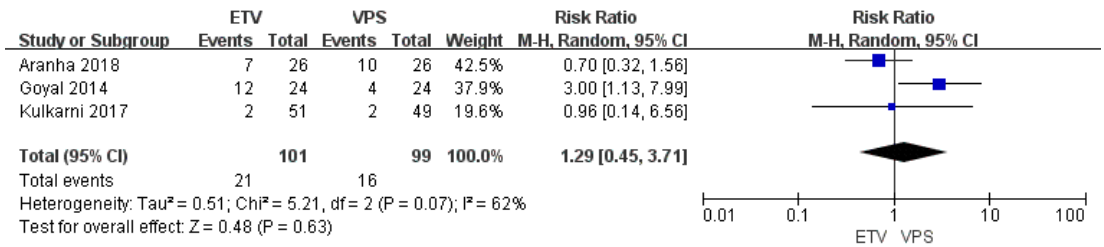

Figure 7. Forest plot for complication rates in general.

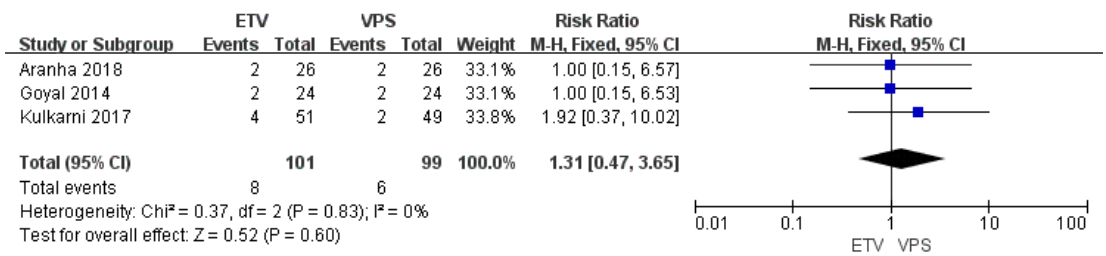

Figure 8. Forest plot for mortality rate.

outcomes 12 months post-surgery for the treatment of idiopathic normal pressure hydrocephalus. Because of the different etiological types of hydrocephalus, for which ETV or VPS may be more appropriate, there is currently no unified standard treatment. Moreover, whether ETV is superior to VPS in the treatment of PIH in PP remains unclear. Due to the complicated treatment of multiloculated hydrocephalus, there was no unified treatment standard at present, which may require repeated revision surgeries, craniotomy or fenestration, or combined with EVT to avoid shunting.[20,32-34] So the treatment of multiloculated hydrocephalus has been temporarily excluded. Thus, we report the first meta-analysis of all ETV- and VPS-related RCTs for the treatment

of PIH in PP. The purpose of this meta-analysis was to compare the efficacy and safety of ETV and VPS. Our meta-analysis demonstrated that VPS and ETV are safe and effective for treating PP with PIH, with the possibility that VPS is superior to ETV.

Our meta-analysis showed that surgical success rates were 59.4% in the ETV group and 66.6% in the VPS group after combining data. There was no significant difference in power between the two components. The postoperative success rate of ETV for PP with PIH is similar to that of previous studies (55.9%,[35] 60%,[30] and 50%[36]). However, Polis *et al*.[15] reported postoperative success rates of 14.7% and 47.77% for ETV and VPS, respectively, which are lower than the rates determined by our meta-analysis. In contrast to the above studies, our study concluded that ETV and VPS are effective for treating PIH as well.

CSF leakage after ETV is a common complication. The incidence of CSF leakage following ETV has been reported to be between 1.6% and 30% in previous studies.[37-40] There were eight patients (1.6%) in the ETV group who had CSF leakage, which was significantly more than the rate of CSF leakage in the VPS group. This may be because the median incision is considered a necessary incision through the catheter from the head to the abdomen during VPS. Early in the course of shunt implantation, intermediate incisions can sometimes crack or the shunt may migrate, which leads to CSF leakage or infection of the shunt system, especially in infant patients. Migration depends on various factors, such as the type of catheter and reservoir used, the fixation technique used, the site and size of the burr hole, and the size of the epidural incision.[41] However, because of the advances in technology, such as the development of a non-intermediate-incision VPS procedure, and the better awareness and prevention of postoperative infection[42,43], migration can be avoided during the treatment of neonates or infants with PIH. Furthermore, even without improving the VPS procedure, the causes of CSF leakage, such as disconnected parts, broken parts, or the entire shunt ware, rarely occur.[41,44] In contrast, after ETV, CSF leakage is more likely because of poorer CSF absorption and the thinning and weakening of the epidural layers of the scalp at the closure, especially in infants.[45] CSF leakage can be a sign of failure of ETV.[46] In our study, the success rate of ETV was slightly lower than that of VPS, and the incidence of CSF leakage was higher following ETV than following VPS. Therefore, we considered that it might indeed be the image of CSF leakage as well.

Shunt surgery has a higher postoperative infection rate in children, with rates as high as 10%–22% per patient and around 6.0% per procedure.[47] Infections, such as meningitis and ventriculitis, have been reported in 1.81% to 6.1% of cases during the immediate postoperative period following ETV surgery.[40,48] Such infectious complications are commonly associated with CSF leakage following ETV, whereas in VPS, the use of implantation materials is commonly associated with infections. In the study of Goyal et al.[24], CSF leakage was reported in seven cases in the ETV group; 14.3% of patients with CSF leakage developed meningitis, of whom one died. Therefore, attention must be paid to the postoperative complications of CSF leakage and infections. In our meta-analysis, the incidence of infection following VPS did not significantly differ from that following ETV (6.1% vs. 4.0%) after pooling data, and the rate of infection was similar to those reported in the above studies.
In addition, nine cases in the ETV group and 10 cases in the VPS group had postoperative blockage, although this difference was not significant.

Although in our analysis, the incidence of CSF leakage complications was higher in the ETV group than that in the VPS group. However, the comparison between the two methods seems to be flawed in terms of CSF leakage. The incidence of ETV combined with CSF leakage is high in literature reports(between 1.6% and 30%), while the incidence of CSF leakage in VPS is only possible when the technique is defective. Therefore, we believe that this simple statistical comparison may be biased, and further comparison of more sample sizes may be needed to assess whether there is a significant difference in the incidence of CSF leakage between the two groups. For this, we also statistically analyzed the complication rates in general of the two groups. Although the complication rates of the VPS group was slightly lower than that of the ETV group, there was no statistical difference between the two groups. This is similar to the previous study[10] on the complication rates of ETV and VPS subgrouped by RCTs.

Texakalidis *et al*. [8] performed a meta-analysis comparing ETV and VPS for pediatric hydrocephalus, which included 8419 patients (not specifically with PIH), and reported all-cause mortality rates of 4.5% and 8.5% for ETV and VPS, respectively. In our study, the mortality rate of ETV (7.9%) was higher than that in the

above study. This may be because we included only RCTs, which limited the sample size. In addition, PIH is the most difficult hydrocephalus type to manage, and the study by Texakalidis *et al*. did not specifically explore PIH. However, it is notable that the mortality rate following VPS (6.1%) in our study was lower than that in the above study. This may indicate that VPS is more advantageous in treating PIH. However, we did not find a statistical difference between ETV and VPS for mortality rate.

There are several limitations to this meta-analysis: 1) only three RCTs with small sample sizes were included in our analysis, which may affect the generalizability of the results, and additional RCTs using large sample sizes are needed for validation; 2) although heterogeneity was not significant, different etiologies of PIH in PP may have introduced some bias; 3) in the combined analysis, ETV and ETV-CPC were combined, which may have biased the results, and further subgroup analyses are needed in future studies. 4)Due to the short follow-up period, we could not know the long-term prognosis of the two surgical methods. Despite these limitations, our meta-analysis was logically and rigorously conducted and may provide a valuable reference for future research.

In conclusion, our meta-analysis showed that the incidence of CSF leakage was higher following ETV than following VPS, which may have an impact on surgical success. However, there were no significant differences between VPS and ETV in postoperative infection rate, postoperative blockage rate, complication rates in general, or mortality rate. Therefore, VPS may be more beneficial for PP with PIH. However, our findings require verification in further RCTs using large sample sizes.

DISCLOSURE

Financial support: None

Conflict of interest: None

REFERENCES

1. Filis AK, Aghayev K, Vrionis FD. Cerebrospinal fluid and hydrocephalus: Physiology, diagnosis, and treatment. *Cancer Control* 2017, 24(1): 6-8. doi:10.1177/107327481702400102.
2. Yamasaki M, Nonaka M, Bamba Y, Teramoto C, Ban C, Pooh RK. Diagnosis, treatment, and long-term outcomes of fetal hydrocephalus. *Semin Fetal Neonatal Med* 2012, 17(6): 330-5. doi:10.1016/j.siny.2012.07.004.
3. Kahle KT, Kulkarni AV, Limbrick DD, Jr., Warf BC. Hydrocephalus in children. *Lancet* 2016; 387(10020): 788-99. doi:10.1016/S0140-6736(15)60694-8.
4. Dewan MC, Rattani A, Mekary R, *et al*. Global hydrocephalus epidemiology and incidence: systematic review et and meta-analysis. *J Neurosurg* 2018: 1-15. doi:10.3171/2017.10.JNS17439.
5. Robert SM, Reeves BC, Marlier A, *et al*. Inflammatory hydrocephalus. *Childs Nerv Syst* 2021; 37(11): 3341-53. doi:10.1007/s00381-021-05255-z.
6. Jernigan SC, Berry JG, Graham DA, Goumnerova L. The comparative effectiveness of ventricular shunt placement versus endoscopic third ventriculostomy for initial treatment of hydrocephalus in infants. *J Neurosurg Pediatr* 2014; 13(3): 295-300. doi:10.3171/2013.11.PEDS13138.
7. Pople IK. Hydrocephalus and shunts: what the neurologist should know. *J Neurol Neurosurg Psychiatry* 2002; 73 (Suppl 1): i17-22. doi:10.1136/jnnp.73.suppl1.i17.
8. Texakalidis P, Tora MS, Wetzel JS, Chern JJ. Endoscopic third ventriculostomy versus shunt for pediatric hydrocephalus: a systematic literature review and meta-analysis. *Childs Nerv Syst* 2019; 35(8): 1283-93. doi:10.1007/s00381-019-04203-2.
9. Lu L, Chen H, Weng S, Xu Y. Endoscopic third ventriculostomy versus ventriculoperitoneal shunt in patients with obstructive hydrocephalus: Meta-analysis of randomized controlled trials. *World Neurosurg* 2019, 129: 334-40. doi:10.1016/j.wneu.2019.04.255.
10. Pande A, Lamba N, Mammi M, *et al*. Endoscopic third ventriculostomy versus ventriculoperitoneal shunt in pediatric and adult population: a systematic review and meta-analysis. *Neurosurg Rev* 2021; 44(3): 1227-41. doi:10.1007/s10143-020-01320-4.
11. Figaji AA, Fieggen AG. Endoscopic challenges and applications in tuberculous meningitis. *World Neurosurg* 2013; 79(2 Suppl): S24 e29-14. doi:10.1016/j.wneu.2012.02.002.
12. Drake JM, Canadian Pediatric Neurosurgery Study G. Endoscopic third ventriculostomy in pediatric patients: the Canadian experience. *Neurosurgery* 2007; 60(5): 881-6; discussion 881-6. doi:10.1227/01.NEU.0000255420.78431.E7.
13. Kadrian D, van Gelder J, Florida D, *et al*. Long-term reliability of endoscopic third ventriculostomy. *Neurosurgery* 2005, 56(6): 1271-8; discussion 1278. doi:10.1227/01.neu.0000159712.48093.ad.
14. Garg K, Gupta D. Post-infective hydrocephalus. *Neurol India* 2021; 69(Supplement): S320-S329. doi:10.4103/0028-3886.332273.
15. Polis B, Polis L, Nowoslawska E. Surgical treatment of post-inflammatory hydrocephalus. Analysis of 101 cases. *Childs Nerv Syst* 2019, 35(2): 237-43. doi:10.1007/s00381-018-4022-4.
16. Deopujari CE, Padayachy L, Azmi A, Figaji A, Samantray SK. Neuroendoscopy for post-infective hydrocephalus in children. *Childs Nerv Syst* 2018; 34(10): 1905-14. doi:10.1007/s00381-018-3901-z.
17. Shamseer L, Moher D, Clarke M, *et al*. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration

and explanation. *BMJ* 2015; 350: g7647. doi:10.1136/bmj.g7647.
18. Schultz P, Leeds NE. Intraventricular septations complicating neonatal meningitis. *J Neurosurg* 1973, 38(5): 620-6. doi:10.3171/jns.1973.38.5.0620.
19. Eller TW, Pasternak JF. Isolated ventricles following intraventricular hemorrhage. J Neurosurg 1985; 62(3): 357-62. doi:10.3171/jns.1985.62.3.0357.
20. Spennato P, Cinalli G, Ruggiero C, *et al*. Neuroendoscopic treatment of multiloculated hydrocephalus in children. *J Neurosurg* 2007; 106(1 Suppl): 29-35. doi:10.3171/ped.2007.106.1.29.
21. Higgins JP, Altman DG, Gotzsche PC, *et al*. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ* 2011, 343: d5928. doi:10.1136/bmj.d5928.
22. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ* 2003, 327(7414): 557-60. doi:10.1136/bmj.327.7414.557.
23. Aranha A, Choudhary A, Bhaskar S, Gupta LN. A randomized study comparing endoscopic third ventriculostomy versus ventriculoperitoneal shunt in the management of hydrocephalus due to tuberculous meningitis. *Asian J Neurosurg* 2018, 13(4): 1140-7. doi:10.4103/ajns.AJNS_107_18.
24. Goyal P, Srivastava C, Ojha BK, *et al*. A randomized study of ventriculoperitoneal shunt versus endoscopic third ventriculostomy for the management of tubercular meningitis with hydrocephalus. *Childs Nerv Syst* 2014; 30(5): 851-7. doi:10.1007/s00381-014-2371-1.
25. Kulkarni AV, Schiff SJ, Mbabazi-Kabachelor E, *et al*. Endoscopic treatment versus shunting for infant hydrocephalus in Uganda. *N Engl J Med* 2017; 377(25): 2456-64. doi:10.1056/NEJMoa1707568.
26. Isaacs AM, Riva-Cambrin J, Yavin D, *et al*. Age-specific global epidemiology of hydrocephalus: Systematic review, metanalysis and global birth surveillance. *PLoS One* 2018; 13(10): e0204926. doi:10.1371/journal.pone.0204926.
27. Zandian A, Haffner M, Johnson J, Rozzelle CJ, Tubbs RS, Loukas M. Endoscopic third ventriculostomy with/without choroid plexus cauterization for hydrocephalus due to hemorrhage, infection, Dandy-Walker malformation, and neural tube defect: a meta-analysis. *Childs Nerv Syst* 2014; 30(4): 571-8. doi:10.1007/s00381-013-2344-9.
28. Chugh A, Husain M, Gupta RK, Ojha BK, Chandra A, Rastogi M. Surgical outcome of tuberculous meningitis hydrocephalus treated by endoscopic third ventriculostomy: prognostic factors and postoperative neuroimaging for functional assessment of ventriculostomy. *J Neurosurg Pediatr* 2009; 3(5): 371-7. doi:10.3171/2009.1.PEDS0947.
29. Husain M, Jha DK, Rastogi M, Husain N, Gupta RK. Role of neuroendoscopy in the management of patients with tuberculous meningitis hydrocephalus. *Neurosurg Rev* 2005; 28(4): 278-83. doi:10.1007/s10143-005-0397-2.
30. Singh D, Sachdev V, Singh AK, Sinha S. Endoscopic third ventriculostomy in post-tubercular meningitic hydrocephalus: a preliminary report. *Minim Invasive Neurosurg* 2005, 48(1): 47-52. doi:10.1055/s-2004-830183.
31. Pinto FC, Saad F, Oliveira MF, *et al*. Role of endoscopic third ventriculostomy and ventriculoperitoneal shunt in idiopathic normal pressure hydrocephalus: preliminary results of a randomized clinical trial. *Neurosurgery* 2013; 72(5): 845-53; discussion 853-844. doi:10.1227/NEU.0b013e318285b37c.
32. Albanese V, Tomasello F, Sampaolo S. Multiloculated hydrocephalus in infants. *Neurosurgery* 1981; 8(6): 641-6. doi:10.1227/00006123-198106000-00001.
33. Oi S, Kudo H, Yamada H, *et al*. Hydromyelic hydrocephalus. Correlation of hydromyelia with various stages of hydrocephalus in postshunt isolated compartments. J Neurosurg 1991; 74(3): 371-9. doi:10.3171/jns.1991.74.3.0371.
34. El-Ghandour NM. Endoscopic cyst fenestration in the treatment of multiloculated hydrocephalus in children. *J Neurosurg Pediatr* 2008; 1(3): 217-22. doi:10.3171/PED/2008/1/3/217.
35. Raouf A, Zidan I, Mohamed E. Endoscopic third ventriculostomy for post-inflammatory hydrocephalus in pediatric patients: is it worth a try? *Neurosurg Rev* 2015; 38(1): 149-55; discussion 155. doi:10.1007/s10143-014-0582-2.
36. Duru S, Peiro JL, Oria M, *et al*. Successful endoscopic third ventriculostomy in children depends on age and etiology of hydrocephalus: outcome analysis in 51 pediatric patients. *Childs Nerv Syst* 2018; 34(8): 1521-8. doi:10.1007/s00381-018-3811-0.
37. Le Fournier L, Delion M, Esvan M, *et al*. Management of hydrocephalus in pediatric metastatic tumors of the posterior fossa at presentation. *Childs Nerv Syst* 2017; 33(9): 1473-80. doi:10.1007/s00381-017-3447-5.
38. Kulkarni AV, Riva-Cambrin J, Holubkov R, *et al*. Endoscopic third ventriculostomy in children: prospective, multicenter results from the Hydrocephalus Clinical Research Network. *J Neurosurg Pediatr* 2016; 18(4): 423-9. doi:10.3171/2016.4.PEDS163.
39. El-Ghandour NM. Endoscopic third ventriculostomy versus ventriculoperitoneal shunt in the treatment of obstructive hydrocephalus due to posterior fossa tumors in children. *Childs Nerv Syst* 2011; 27(1): 117-26. doi:10.1007/s00381-010-1263-2.
40. Bouras T, Sgouros S. Complications of endoscopic third ventriculostomy. *J Neurosurg Pediatr* 2011; 7(6): 643-9. doi:10.3171/2011.4.PEDS10503.
41. Acharya R, Bhutani A, Saxena H, Madan VS. Complete migration of ventriculoperitoneal shunt into the ventricle. *Neurol Sci* 2002; 23(2): 75-7. doi:10.1007/s100720200029.
42. Hamauchi S, Seki T, Sasamori T, Houkin K. Development of a nonintermediate-incision ventriculoperitoneal shunt procedure using a nasogastric feeding tube for infant patients with hydrocephalus: technical note. *J Neurosurg Pediatr* 2016; 17(5): 540-3. doi:10.3171/2015.9.PEDS15464.
43. Sandquist MA, Selden NR. A single-pass tunneling technique for CSF shunting procedures. *Pediatr Neurosurg* 2003; 39(5): 254-7. doi:10.1159/000072870.
44. Yousaf I, Choudhari KA. Spontaneous intracranial migration of the shunt chamber. *Br J Neurosurg* 2003; 17(5): 465-6. doi:10.1080/02688690310001611279.

45. Jung TY, Chong S, Kim IY, *et al*. Prevention of complications in endoscopic third ventriculostomy. *J Korean Neurosurg Soc* 2017; 60(3): 282-8. doi:10.3340/jkns.2017.0101.014.
46. Kombogiorgas D, Sgouros S. Assessment of the influence of operative factors in the success of endoscopic third ventriculostomy in children. *Childs Nerv Syst* 2006; 22(10): 1256-62. doi:10.1007/s00381-006-0072-0.
47. Habibi Z, Ertiaei A, Nikdad MS, *et al*. Predicting ventriculoperitoneal shunt infection in children with hydrocephalus using artificial neural network. *Childs Nerv Syst* 2016; 32(11): 2143-51. doi:10.1007/s00381-016-3248-2.
48. Bouras T, Sgouros S. Complications of endoscopic third ventriculostomy. *World Neurosurg* 2013; 79(2 Suppl): S22 e29-12. doi:10.1016/j.wneu.2012.02.014.